

768 moves with the linear actuator 822 while the distal coupler 767 is fixed relative to a non-moving end of the linear actuator 822.

[0638] FIG. 79 shows a close-up of the valve 769 of FIGS. 77-78. The valve 769 includes two strips 771, 772 (which may be metallic strips) in which the tube 775 may be disposed. The two strips 771, 772 of the valve 769 may be coupled to a first end structure 773 and a second end structure 774. The first end structure 773 may be coupled to the distal coupler 767 and the second end structure 774 may be coupled to the proximal coupler proximal coupler 768 (see FIGS. 77-78). A string 770 or membrane may be wrapped around the tube 775 such that, when the strips 771, 772 are straightened out, the string 770 presses against the side walls of the tube 775 to help round the tube 775. The membrane may be a flexible, but not stretchable, material (or minimally stretchable material). FIG. 80 shows a close-up of the valve as actuated in FIG. 78. Note the holes 776 and 778 that the string 770 is threaded through. The string 770 (which may be metallic) is spiraled around the tube 775 such that when the valve 769 opens, the string 770 restores the tube 775.

[0639] FIG. 81 shows several images for use to illustrate a method of estimating drop growth and/or fluid flow illustrated in FIGS. 82A-82B in accordance with an embodiment of the present disclosure. FIG. 81 shows images 771-777 which are referred to below regarding FIGS. 82A-82B.

[0640] FIGS. 82A-82B show a flow chart diagram illustrating a method 803 of estimating drop growth and/or fluid flow. The method 803 includes acts 804-818.

[0641] Act 804 captures a first image (e.g., image 771 of FIG. 81). The first image may be a grey scale image of the drip chamber. The drip chamber may be uniformly lit with a striped pattern on the bottom of the chamber (i.e., there is no back pattern on the top portion of the drip chamber).

[0642] Act 805 creates a first thresholded image using the first image. The first thresholded image may be the image 774 of FIG. 81. The first thresholded image may be made by comparing each pixel from the first image to a threshold value (e.g., setting a respective pixel of the thresholded image to 0 if the respective pixel of the first image is above the threshold or setting a respective pixel of the thresholded image to 1 if the respective pixel of the first image is below the threshold). This act is to highlight areas where there is water in front of the background.

[0643] In some specific embodiments, the threshold level is updated every time a new image is taken to ensure a predetermined ratio of 1 to 0 pixels is maintained to highlight the drop. The ratio may be updated for use by act 805 when used again or the update may adjust the threshold until a predetermined ratio of 1 to 0 pixels is made and then use the first thresholded image for the rest of the method 803.

[0644] Act 806 determines a set of pixels within the first thresholded image connected to a predetermined set of pixels within the first thresholded image. The predetermined set of pixels may be determined by fiducials marked on the drip chamber or an opening in which drops are formed. The predetermined set of pixels may be a predetermined set of x, y values that correspond to pixels. Act 806 may use a connected component image analysis algorithm.

[0645] Act 807 filters all remaining pixels of the first thresholded image that are not within the set of pixels. The filter operates on a pixel-by-pixel basis within the time

domain to generate a first filtered image. The first filtered image is an estimate of a non-active (e.g., a result from features not of interest in the image) portion of the first thresholded image (image 774 of FIG. 81). The filter may be any filter, e.g., any filter described herein.

[0646] Act 808 removes pixels determined to not be part of a drop from the first thresholded image using the first filtered image to generate a second image (e.g., image 775 of FIG. 81). A pixel within the second image will be set to 1 if a respective pixel in the first thresholded image is 1 and a respective pixel in the first filtered image is less than 0.5; otherwise, the pixel will be set to 0.

[0647] Act 809 determines a second set of pixels within the second image connected to a predetermined set of pixels within the second image to generate a third image (e.g., the image 776 of FIG. 81). The third image identifies the second set of pixels within the second image. Act 809 finds the set of "lit" pixels in the second image connected to the predetermined set of pixels (e.g., pixels representing the opening in which drops are formed).

[0648] Act 810 determines a first length of the drop by counting the number of rows containing pixels corresponding to the second set of pixels within the third image. That is, the drop length is determined to be equal to the last "lit" row in the set of pixels found in Act 809. The first length corresponds to a first estimated drop size.

[0649] Act 811 updates a background image using the first image. A low-pass filter may be used to update each pixel's value in the background image. An infinite impulse response filter may be used to update the background image using the first image. A pixel is only updated in the background image for rows below the first length plus a predetermined safety zone. A pixel in the background image is updated by low pass filtering the value from the corresponding pixel in the first image.

[0650] Act 812 creates a second thresholded image (e.g., image 772 of FIG. 81) by comparing the first image with the background image. That is, the first image has the background image subtracted from it, and on a pixel-by-pixel basis, the absolute value of each pixel is set to 1 if it is above a second threshold value and is set to a 0 if it is below the second threshold value to generate the second thresholded image.

[0651] Act 813 sums the rows of the second thresholded image to create a plurality of row sums (see image 773 of FIG. 81). Each row sum corresponds to a row of the second thresholded image.

[0652] Act 814 starts at a row position of the second thresholded image having a first sum of the plurality of sums that corresponds to the first length. The row position is incremented in act 815. Act 816 determines whether the present row position correspond to a corresponding row sum that is below a threshold, e.g., zero. If no, then act 815 is performed again until the present row position corresponds to a corresponding row sum that is zero and then the method 803 proceeds to act 817.

[0653] Act 817 determines a second length is equal to the present row position. The second length corresponding to a second estimated drop size. Act 818 averages the first and second lengths to determine an average length. The average length corresponding to a third estimated drop size. By using the first and second lengths to determine an average length, the effects of condensation on the inner walls of the drip chamber are mitigated. That is, the purpose of creating two